CBSE 12 2025 Chemistry Set 2 (56/2/2) Question Paper with Solutions

Time Allowed :3 hours	**Maximum Marks :**70	**Total Questions :**33

General Instructions

Read the following instructions very carefully and strictly follow them :

(i) This question paper contains 33 questions. All questions are compulsory.

(ii) This question paper is divided into five sections — Section A, B, C, D and E.

(iii) Section A - questions number 1 to 16 are multiple choice type questions. Each question carries 1 mark.

(iv) Section B - questions number 17 to 21 are very short answer type questions. Each question carries 2 marks.

(v) Section C - questions number 22 to 28 are short answer type questions. Each q ype q question carries 8 marks.

(vi) Section D - questions number 29 and 30 are case-based questions. Each question carries 4 marks.

(vii) Section E - questions number 31 to 33 are long answer type questions. Each question carries 5 marks.

(viii) There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the sections except Section A.

(ix) Kindly note that there is a separate question paper for Visually Impaired candidates.

(x) Use of calculators is not allowed.

SECTION A

Questions no. 1 to 16 are Multiple Choice type Questions, carrying 1 mark each

1. Assertion (A): Vitamin D cannot be stored in our body. Reason (R): Vitamin D is fat-soluble vitamin and is not excreted from the body in urine.

(1) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(2) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(3) Assertion (A) is true, but Reason (R) is false.

(4) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (3) Assertion (A) is true, but Reason (R) is false.

Solution: Vitamin D, classified as a fat-soluble vitamin, behaves differently from water-soluble vitamins such as vitamin C and the B vitamins. The primary characteristic of fat-soluble vitamins is their ability to be stored in the body's fatty tissues and liver. This means that when you consume vitamin D, it is absorbed through the intestines, transported via the bloodstream, and then stored in the fat cells and liver for later use. This characteristic makes Assertion (A) true, as it correctly states that Vitamin D is a fat-soluble vitamin.

The confusion arises with Reason (R), which incorrectly states that Vitamin D is excreted from the body in urine. This is not accurate for fat-soluble vitamins. Unlike water-soluble vitamins, which are excreted through urine when in excess, fat-soluble vitamins like Vitamin D are stored in the body. They do not get excreted through the urinary system; instead, they remain in fat and liver tissues for future utilization. This makes Reason (R) false.

Step 2: Thus, based on the explanation above, the correct answer is option (3).

Quick Tip
It's important to remember the distinction between fat-soluble and water-soluble vitamins. Fat-soluble vitamins like Vitamin D, A, E, and K are stored in the liver and fatty tissues, while water-soluble vitamins are not stored in the body and are usually excreted through urine when in excess.

2. Assertion (A): Aromatic primary amines cannot be prepared by Gabriel Phthalimide synthesis. Reason (R): Aryl halides do not undergo nucleophilic substitution reaction with the anion formed by phthalimide.

(1) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(2) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(3) Assertion (A) is true, but Reason (R) is false.

(4) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (2) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

Solution:

The Gabriel Phthalimide synthesis is a well-known method for synthesizing primary amines, but it is not effective for preparing aromatic amines. The reason for this is that aryl halides do not undergo nucleophilic substitution reactions with the phthalimide anion. This is due to the poor leaving group ability of the halides in aryl compounds, which hinders the substitution process. However, this issue is not the primary reason why aromatic primary amines cannot be synthesized using this method.

Step 2: Therefore, while both Assertion (A) and Reason (R) are true, Reason (R) does not correctly explain the statement in Assertion (A).

Quick Tip
The Gabriel synthesis is an effective method for preparing primary amines from alkyl halides, but it does not work well with aryl halides due to their poor reactivity in nucleophilic substitution reactions.

3. Assertion (A): Cu cannot liberate H_2 on reaction with dilute mineral acids. Reason (R): Cu has positive electrode potential.

(1) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(2) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(3) Assertion (A) is true, but Reason (R) is false.
(4) Assertion (A) is false, but Reason (R) is true.
Correct Answer: (4) Assertion (A) is false, but Reason (R) is true.

Solution:
Copper (Cu) does not release hydrogen gas when it reacts with dilute mineral acids because it is a less reactive metal. Due to its low reactivity, copper is unable to displace hydrogen from the acids. While copper has a positive electrode potential, which indicates that it is less prone to losing electrons and participating in such reactions, this property does not directly explain why it does not release hydrogen gas.

Step 2: Therefore, Assertion (A) is incorrect, while Reason (R) is true, but they are not logically linked to each other.

Quick Tip
Metals such as copper, with a positive electrode potential, are less reactive and do not readily produce hydrogen gas when reacting with dilute acids.

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4. Assertion (A): In a first order reaction, if the concentration of the reactant is doubled, its half-life is also doubled. Reason (R): The half-life of a reaction does not depend upon the initial concentration of the reactant in a first order reaction.
(1) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(2) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(3) Assertion (A) is true, but Reason (R) is false.
(4) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (4) Assertion (A) is false, but Reason (R) is true.

Solution: In the case of a first-order reaction, the half-life is constant and does not depend on the initial concentration of the reactant. This means the half-life remains the same, regardless of any changes in the concentration of the reactant over time. Therefore, Assertion (A) is incorrect, while Reason (R) is correct.

Step 2: Thus, Assertion (A) is false, and Reason (R) is true.

Quick Tip
In first-order reactions, the half-life is unaffected by the concentration of reactants, which is a distinctive characteristic of these reactions.

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5. Scurvy is caused due to deficiency of

(1) Vitamin B1

(2) Vitamin B2

(3) Ascorbic acid

(4) Glutamic acid

Correct Answer: (3) Ascorbic acid

Solution: Scurvy is a condition that results from a lack of Vitamin C, also known as ascorbic acid. Vitamin C plays a vital role in the synthesis of collagen, a key protein that supports the structure of connective tissues in the body.

Step 2: Therefore, the correct answer is option (3).

Quick Tip
Vitamin C (ascorbic acid) is essential for the formation of collagen and the maintenance of connective tissues. A deficiency in this vitamin leads to scurvy.

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6. Nucleotides are joined together by

(1) Glycosidic linkage

(2) Peptide linkage

(3) Hydrogen bonding

(4) Phosphodiester linkage

Correct Answer: (4) Phosphodiester linkage

Solution: In nucleic acids such as DNA and RNA, nucleotides are linked together by phosphodiester bonds. These bonds occur when a phosphate group attaches the 3' carbon of one sugar molecule to the 5' carbon of the next sugar molecule in the chain.

Step 2: Therefore, the correct answer is option (4).

Quick Tip
Phosphodiester bonds form the structural backbone of nucleic acids, linking the sugar and phosphate groups of consecutive nucleotides.

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7. Which of the following is/are examples of denaturation of protein?

(1) Coagulation of egg white

(2) Curdling of milk

(3) Clotting of blood

(4) Both (1) and (2)

Correct Answer: (4) Both (1) and (2)

Solution: Protein denaturation occurs when proteins lose their original structure due to external influences such as changes in temperature or pH levels. The processes of egg white coagulation and milk curdling are both examples of protein denaturation.

Step 2: Thus, the correct answer is option (4).

Quick Tip
Proteins can denature when exposed to heat, acid, or mechanical forces, resulting in the disruption of their functional shape.

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8. The conversion of phenol to salicylic acid can be accomplished by

(1) Reimer-Tiemann reaction

(2) Friedel-Crafts reaction

(3) Kolbe reaction

(4) Coupling reaction

Correct Answer: (1) Reimer-Tiemann reaction

Solution: The Reimer-Tiemann reaction is employed to convert phenols into salicylic acid. In this process, phenol is treated with chloroform and a base, resulting in the formation of salicylic acid.

Step 2: Therefore, the correct answer is option (1).

Quick Tip
The Reimer-Tiemann reaction consists of the chlorination of phenol followed by hydrolysis, producing salicylic acid, which is a key precursor for aspirin.

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9. What will be formed after oxidation of secondary alcohol with chromic anhydride (CrO_3)?

(1) Aldehyde

(2) Ketone

(3) Carboxylic acid

(4) Ester

Correct Answer: (2) Ketone

Solution: When a secondary alcohol is oxidized with chromic anhydride (CrO_3), it is converted into a ketone. Secondary alcohols do not undergo oxidation to form aldehydes or carboxylic acids.

Step 2: Therefore, the correct answer is option (2).

Quick Tip

Chromic anhydride is a powerful oxidizing agent that specifically oxidizes secondary alcohols to ketones, without affecting aldehydes or carboxylic acids.

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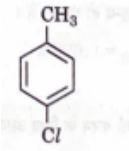
10. Which is the correct IUPAC name for



(1) Methylchlorobenzene

(2) Toluene

(3) 1-Chloro-4-Methylbenzene

(4) 1-Methyl-4-Chlorobenzene

Correct Answer: (3) 1-Chloro-4-Methylbenzene

Solution: The compound contains both a methyl group and a chlorine atom attached to a benzene ring. The appropriate IUPAC name is 1-Chloro-4-Methylbenzene, where the numbering begins from the position of the chlorine atom and continues to the position of the methyl group.

Step 2: Therefore, the correct answer is option (3).

Quick Tip

For aromatic compounds with multiple substituents, the substituents should be numbered in such a way that the locants are as low as possible, with the substituents listed in alphabetical order.

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11. The diamagnetic species is :

At. No. Co = 27, Fe =26, Ni= 28]

(1) $[Ni(CN)_4]^{2-}$

(2) $[NiCl_4]^{2-}$

(3) $[Fe(CN)_6]^{3-}$

(4) $[CoF_6]^{3-}$

Correct Answer: (1) $[Ni(CN)_4]^{2-}$

Solution: Diamagnetic substances are those that do not contain any unpaired electrons. Among the given options, $[Ni(CN)_4]^{2-}$ is diamagnetic because the Ni^{2+} ion in this complex has no unpaired electrons.

Step 2: Therefore, the correct answer is option (1).

Quick Tip
Diamagnetic species have all electrons paired and are repelled by magnetic fields, in contrast to paramagnetic species, which possess unpaired electrons.

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12. The complex ions $[Co(NH_3)_5(NO_2)]^{2+}$ and $[Co(NH_3)_5(ONO)]^{2+}$ are called

(1) Ionization isomers

(2) Linkage isomers

(3) Co-ordination isomers

(4) Geometrical isomers

Correct Answer: (2) Linkage isomers

Solution: Linkage isomerism arises when a ligand can coordinate to a metal ion in two distinct ways. In this case, NO_2 and ONO are two different forms of the same ligand, resulting in linkage isomerism.

Step 2: Hence, the correct answer is option (2).

Quick Tip
Linkage isomerism occurs when a ligand binds to a metal ion through different atoms, creating isomers that have the same molecular formula but distinct structural arrangements.

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13. The element having $[Ar]3d^{10}4s^1$ electronic configuration is

(1) Cu

(2) Zn

(3) Cr

(4) Mn

Correct Answer: (1) Cu

Solution: The electron configuration $[Ar]3d^{10}4s^1$ is characteristic of Copper (Cu), which has an atomic number of 29.

Step 2: Therefore, the correct answer is option (1).

Quick Tip
Copper (Cu) follows the electron configuration $[Ar]3d^{10}4s^1$, which deviates from the usual pattern due to the enhanced stability provided by a fully filled 3d subshell.

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14. The number of molecules that react with each other in an elementary reaction is a measure of the:

(1) activation energy of the reaction

(2) stoichiometry of the reaction

(3) molecularity of the reaction

(4) order of the reaction

Correct Answer: (3) molecularity of the reaction

Solution: Molecularity of a reaction refers to the number of reactant molecules that participate in an elementary reaction. It is an essential concept used to understand the reaction mechanism.

Step 2: Therefore, the correct answer is option (3).

Quick Tip

Molecularity represents the number of reactant molecules that collide in an elementary step to initiate a reaction.

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15. Which among the following is a false statement?

(1) Rate of zero order reaction is independent of initial concentration of reactant.

(2) Half-life of a zero order reaction is inversely proportional to the rate constant.

(3) Molecularity of a reaction may be zero.

(4) For a first order reaction, $t_{1/2} = 0.693/k$.

Correct Answer: (3) Molecularity of a reaction may be zero.

Solution: Molecularity refers to the number of reacting species in an elementary reaction, and it cannot be zero. A reaction cannot take place without any reacting molecules.

Step 2: Therefore, the correct answer is option (3).

Quick Tip

Molecularity is always a positive integer, indicating the number of molecules involved in an elementary reaction step.

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16. The charge required for the reduction of 1 mol of MnO_4^- to MnO_2 is

(1) 1 F

(2) 3 F

(3) 5 F

(4) 6 F

Correct Answer: (3) 5 F

Solution: In the reduction of MnO_4^- to MnO_2, the manganese ion undergoes a change in oxidation state from +7 to +4, which requires 5 moles of electrons. Hence, the charge required is 5 F (Faradays).

Step 2: Thus, the correct answer is option (3).

Quick Tip
The number of Faradays required for a redox reaction corresponds to the total number of electrons involved in the oxidation or reduction of the species.

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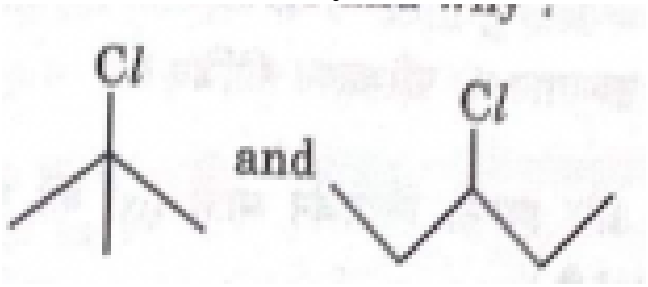
17. (a) In the following pair of halogen compounds, which compound undergoes S_N1 reaction faster and why?



Solution: Step 1: Understanding the S_N1 Mechanism.

The S_N1 reaction follows a two-step process:

1. Formation of a carbocation (the rate-determining step).

2. Nucleophilic attack on the carbocation.

The rate of the S_N1 reaction is influenced by the stability of the carbocation. Tertiary carbocations are more stable due to greater alkyl group substitution, which provides enhanced electron donation through hyperconjugation and inductive effects. This increased stability facilitates faster carbocation formation, thereby accelerating the reaction rate.

When comparing two halogen compounds, the one with the tertiary halogenated carbon (more substituted carbon) will form a more stable carbocation and therefore undergo the S_N1 reaction at a faster rate.

Quick Tip
Keep in mind that in S_N1 reactions, the stability of the carbocation intermediate is key. More substituted carbocations are typically more stable and form more quickly, speeding up the overall reaction.

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17. (b) Arrange the following compounds in increasing order of their reactivity towards S_N2 displacement: 2-Bromo-2-methylbutane, 1-Bromopentane, 2-Bromopentane.

Solution: Step 1: Understanding the S_N2 Mechanism.

The S_N2 mechanism occurs in a single step where the nucleophile simultaneously attacks the electrophilic carbon and displaces the leaving group. This process is highly sensitive to steric hindrance; thus, carbons with fewer substituents are more reactive because they offer easier access to the nucleophile.

2-Bromo-2-methylbutane: Being a tertiary bromide, this compound is highly hindered, making S_N2 reactions very slow.

2-Bromopentane: As a secondary bromide, it is less hindered than the tertiary one but still more so than a primary bromide, placing it in the middle in terms of reactivity.

1-Bromopentane: This is a primary bromide with minimal steric hindrance, which promotes the fastest S_N2 reaction.

Thus, the order of increasing reactivity towards S_N2 displacement is:

$$\text{2-Bromo-2-methylbutane} < \text{2-Bromopentane} < \text{1-Bromopentane}.$$

Quick Tip
For S_N2 reactions, remember that less steric hindrance at the reaction center results in a faster reaction. Primary halides are generally more reactive than secondary and tertiary halides.

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18. A reaction is of second order with respect to a reactant. How is the rate of reaction affected if the concentration of the reactant is (i) doubled, (ii) reduced to half?

Solution: Step 1: Understanding Second-Order Reactions. For a second-order reaction, the rate law is expressed as:

$$\text{Rate} = k[A]^2$$

where $[A]$ represents the concentration of the reactant, and k is the rate constant.

Step 2: Effect of Concentration Change. (i) If the concentration of A is doubled, the rate will increase by a factor of $2^2 = 4$ because the rate is proportional to the square of the

concentration.

$$\text{New Rate} = k(2[A])^2 = 4k[A]^2$$

(ii) If the concentration of A is halved, the rate will decrease by a factor of $\left(\frac{1}{2}\right)^2 = \frac{1}{4}$.

$$\text{New Rate} = k\left(\frac{1}{2}[A]\right)^2 = \frac{1}{4}k[A]^2$$

Thus, doubling the concentration increases the rate by a factor of 4, while halving the concentration reduces the rate to one-quarter.

Quick Tip
For second-order reactions, the rate is proportional to the square of the concentration. Doubling the concentration increases the rate by a factor of 4, and halving it decreases the rate by a factor of 4.

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19. When $FeCr_2O_4$ is fused with Na_2CO_3 in the presence of air, it gives a yellow solution of compound (A). Compound (A) on acidification gives compound (B). Compound (B) on reaction with KCl forms an orange-colored compound (C). An acidified solution of compound (C) oxidizes Na_2SO_3 to (D). Identify (A), (B), (C), and (D).

Solution: Step 1: Identifying Compound (A).

When $FeCr_2O_4$ is fused with Na_2CO_3 in the presence of air, it produces a yellow solution of sodium chromate (Na_2CrO_4).

Thus, $A = Na_2CrO_4$.

Step 2: Identifying Compound (B).

Upon acidifying Na_2CrO_4, it is converted to potassium dichromate ($K_2Cr_2O_7$), which is orange in color.

Thus, $B = K_2Cr_2O_7$.

Step 3: Identifying Compound (C).

When $K_2Cr_2O_7$ reacts with KCl, it forms orange-colored $Cr_2O_7^{2-}$ ions. Hence, C is an orange-colored chromium compound.

Thus, $C = K_2Cr_2O_7$.

Step 4: Identifying Compound (D).

An acidified solution of C oxidizes sodium sulfite (Na_2SO_3) to sodium sulfate (Na_2SO_4). This is a typical redox reaction where chromium compounds act as oxidizing agents.

Thus, $D = Na_2SO_4$.

So, the identities are:

$A = Na_2CrO_4$

$B = K_2Cr_2O_7$

$C = K_2Cr_2O_7$

$D = Na_2SO_4$

Quick Tip
Chromates and dichromates are powerful oxidizing agents. Chromates appear yellow in alkaline conditions, while dichromates appear orange in acidic conditions.

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20. Explain $[Co(NH_3)_6]^{3+}$ is an inner orbital complex whereas $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex. [At. No. Co = 27, Ni = 28]

Solution: Step 1: Understanding Inner and Outer Orbital Complexes. Inner orbital complexes involve the use of d-orbitals from the inner shell (typically the $3d$-orbitals in transition metals). This type of hybridization leads to low-spin complexes, where ligands coordinate using these inner d-orbitals.

Outer orbital complexes involve the use of d-orbitals from the outer shell (typically $4d$-orbitals for transition metals in higher oxidation states). This type of hybridization leads to high-spin complexes, where ligands coordinate using these outer d-orbitals.

Step 2: Identifying the Hybridization in $[Co(NH_3)_6]^{3+}$. Cobalt in the $+3$ oxidation state has an electronic configuration of $3d^6$, and the complex $[Co(NH_3)_6]^{3+}$ uses inner $3d$-orbitals for bonding with the ligands. The $3d^2sp^3$ hybridization results in an inner orbital complex.

Step 3: Identifying the Hybridization in $[Ni(NH_3)_6]^{2+}$. Nickel in the $+2$ oxidation state has an electronic configuration of $3d^8$, and the complex $[Ni(NH_3)_6]^{2+}$ uses outer $4d$-orbitals for bonding. The sp^3d^2 hybridization results in an outer orbital complex.

Thus, $[Co(NH_3)_6]^{3+}$ is an inner orbital complex, while $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex.

Quick Tip

For inner orbital complexes, low-spin configurations are typical with d^2sp^3 hybridization. For outer orbital complexes, high-spin configurations are typical with sp^3d^2 hybridization.

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21. (A) The rate constant for a zero-order reaction $A \to P$ is 0.0030 mol L^{-1} s^{-1}. How long will it take for the initial concentration of A to fall from 0.10 M to 0.075 M?

Solution: For a zero-order reaction, the integrated rate law is given by:

$$[A] = [A_0] - kt$$

where:

$[A]$ represents the concentration of A at time t,

$[A_0]$ is the initial concentration,

k is the rate constant, and

t is the time elapsed.

Given values are:

$[A_0] = 0.10\,\text{M}$,

$[A] = 0.075\,\text{M}$,

$k = 0.0030\,\text{mol L}^{-1}\,\text{s}^{-1}$.

Substituting these values into the rate law:

$$0.075 = 0.10 - (0.0030)(t)$$

Rearranging to solve for t:

$$0.0030t = 0.10 - 0.075 = 0.025$$

$$t = \frac{0.025}{0.0030} = 8.33\,\text{seconds}$$

Thus, it will take approximately 8.33 seconds for the concentration of A to decrease from 0.10 M to 0.075 M.

Quick Tip
In zero-order reactions, concentration decreases at a constant rate over time. The time for a specific concentration change can be determined using the integrated rate law.

OR

21. (B) The decomposition of NH_3 on a platinum surface is a zero-order reaction. What are the rates of production of N_2 and H_2 if $k = 2.5 \times 10^{-4}$ mol L^{-1} s^{-1}?

Solution: In a zero-order reaction, the rate of reaction remains constant and is equal to the rate constant k. The rate of product formation is directly proportional to this rate constant. In this case, the rate constant is $k = 2.5 \times 10^{-4}$ mol L^{-1} s^{-1}.

For the decomposition of NH_3 on the platinum surface, the products N_2 and H_2 are produced in a 1:3 molar ratio. As a result, the rates of production of both N_2 and H_2 will be equal to the rate constant k.

Thus, the rates of production of N_2 and H_2 are both:

$$\text{Rate of production of } N_2 = \text{Rate of production of } H_2 = 2.5 \times 10^{-4} \text{ mol } L^{-1} s^{-1}.$$

Quick Tip
In zero-order reactions, the rate of product formation remains constant and is equal to the rate constant, irrespective of the reactant concentration.

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22. A solution containing 15 g urea (molar mass = 60 g mol^{-1}) per litre of solution in water has the same osmotic pressure (isotonic) as a solution of glucose (molar mass = 180 g mol^{-1}) in water. Calculate the mass of glucose present in one litre of its solution.

Solution: Osmotic pressure (π) is given by the formula:

$$\pi = \frac{nRT}{V}$$

where:

n is the number of moles of solute,

R is the gas constant,

T is the temperature,

V is the volume of the solution.

Since both solutions have the same osmotic pressure, the number of moles of solute in both solutions must be equal. For urea, the number of moles n_1 is calculated as:

$$n_1 = \frac{15\,\text{g}}{60\,\text{g/mol}} = 0.25\,\text{mol}.$$

Let the mass of glucose be m_2. The number of moles of glucose n_2 is:

$$n_2 = \frac{m_2}{180\,\text{g/mol}}.$$

Since the osmotic pressures are identical, the number of moles of urea must equal the number of moles of glucose:

$$0.25 = \frac{m_2}{180}.$$

Solving for m_2:

$$m_2 = 0.25 \times 180 = 45\,\text{g}.$$

Therefore, the mass of glucose present in one litre of its solution is $45\,\text{g}$.

Quick Tip
When two solutions have the same osmotic pressure, the number of moles of solute is inversely proportional to the molar mass of the solute.

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23. Calculate Λ_m^0 for acetic acid and its degree of dissociation (α) if its molar conductivity is 48.1 $\Omega^{-1}\,\text{cm}^2\,\text{mol}^{-1}$.

Given that

$\Lambda_m^0(\textbf{HC}) = 426\,\Omega^{-1}\,\textbf{cm}^2\,\textbf{mol}^{-1}$,

$\Lambda_m^0(\textbf{NaCl}) = 126\,\Omega^{-1}\,\textbf{cm}^2\,\textbf{mol}^{-1}$,

$\Lambda_m^0(\textbf{CH}_3\textbf{COONa}) = 91\,\Omega^{-1}\,\textbf{cm}^2\,\textbf{mol}^{-1}$.

Solution: First, we need to calculate the molar conductivity at infinite dilution, Λ_m^0, for acetic acid, which is the sum of the conductivity contributions from the ions of acetic acid

and sodium acetate:

$$\Lambda_m^0(\text{Acetic acid}) = \Lambda_m^0(\text{HC}) - \Lambda_m^0(\text{NaCl}) = 426 - 126 = 300\,\Omega^{-1}\,\text{cm}^2\,\text{mol}^{-1}.$$

Next, we can calculate the degree of dissociation α by comparing the observed molar conductivity of acetic acid to its expected conductivity at infinite dilution:

$$\alpha = \frac{\Lambda_m}{\Lambda_m^0}.$$

Substituting the given values:

$$\alpha = \frac{48.1}{300} \approx 0.16.$$

Thus, the degree of dissociation α is 0.16, and the molar conductivity at infinite dilution for acetic acid is 300 $\Omega^{-1}\,\text{cm}^2\,\text{mol}^{-1}$.

Quick Tip
The degree of dissociation α represents the proportion of the total molecules that dissociate into ions in a solution.

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24. (a) Why is Cr^{2+} strongly reducing while Mn^{3+} is strongly oxidizing?

Solution: Chromium in the Cr^{2+} state has an electronic configuration of $[Ar]3d^4$, which is relatively unstable and easily oxidizes to the more stable Cr^{3+} configuration, $[Ar]3d^5$. This instability makes Cr^{2+} a strong reducing agent because it readily loses electrons.
In contrast, Mn^{3+} has an electronic configuration of $[Ar]3d^4$, which is also unstable. It tends to gain electrons to achieve the more stable Mn^{2+} configuration, $[Ar]3d^5$. Hence, Mn^{3+} acts as a strong oxidizing agent, readily accepting electrons.

Step 2: The differences in the electronic configurations of Cr^{2+} and Mn^{3+} explain why Cr^{2+} is a strong reducing agent and Mn^{3+} is a strong oxidizing agent.

Quick Tip
Elements with unstable electronic configurations in certain oxidation states (like Cr^{2+} or Mn^{3+}) are more likely to either gain or lose electrons to reach more stable configurations.

24. (b) Write two consequences of lanthanide contraction.

Solution: Lanthanide contraction refers to the gradual reduction in the ionic radius of the lanthanide series as the atomic number increases, due to the ineffective shielding of the 4f-electrons. Two significant consequences of lanthanide contraction are:

1. Decreasing ionic radii: As the atomic number increases from La^{3+} to Lu^{3+}, the size of the ions decreases. This results in a higher effective nuclear charge acting on the electrons, causing the ionic radii to shrink.

2. Similarity between 3d and 4d/5d elements: Lanthanide contraction creates similarities in the properties of the lanthanide elements and the d-block elements in the same period. For example, Zr (a 4d element) and Hf (a 5d element) exhibit very similar ionic radii due to this contraction.

Step 2: Thus, lanthanide contraction leads to smaller ionic radii and greater similarities in the properties of lanthanides and d-block elements.

Quick Tip
The lanthanide contraction accounts for many of the similarities in the properties of d-block and f-block elements, especially concerning ionic radii and chemical behavior.

24. (c) Which element of the 3d series has the lowest enthalpy of atomisation and why?

Solution: The element in the 3d series with the lowest enthalpy of atomisation is copper (Cu). Copper has a completely filled $3d^{10}$ configuration, which contributes to its high stability. This stable electron configuration reduces the energy required to break the metallic bonds during atomisation, resulting in a lower enthalpy of atomisation.

In comparison, elements like zinc (Zn) and manganese (Mn) have less stable electron configurations, requiring more energy to break the metallic bonds during atomisation.

Step 2: Therefore, copper (Cu) has the lowest enthalpy of atomisation due to the stability provided by its filled $3d^{10}$ configuration.

Quick Tip

Elements with stable electron configurations, such as copper's $3d^{10}$, have lower enthalpies of atomisation because less energy is needed to break the bonds.

---

25. Write IUPAC names of the following coordination entities:

(a) $[Fe(en)_2Cl_2]^+$

(b) $[Co(NH_3)_4(H_2O)Br]SO_4$

(c) $[Ni(CN)_4]^{2-}$

Solution: (a) $[Fe(en)_2Cl_2]^+$

In this complex:

The metal ion is Fe^{3+}, representing iron in the +3 oxidation state.

en stands for ethylenediamine, a bidentate ligand.

Chlorine (Cl) acts as a monodentate ligand.

The overall charge of the complex is +1.

The IUPAC name for this complex is:

$$\text{bis(ethylenediamine)(chlorido)iron(III)}^+$$

(b) $[Co(NH_3)_4(H_2O)Br]SO_4$

In this complex:

The metal ion is Co^{3+}, cobalt in the +3 oxidation state.

NH_3 is ammonia, a monodentate ligand.

H_2O is water, also a monodentate ligand.

Br is bromide, a monodentate ligand.

The anion SO_4^{2-} balances the charge.

The IUPAC name for this complex is:

$$\text{tetraammin(aqua)bromidocobalt(III) sulfate}$$

(c) $[Ni(CN)_4]^{2-}$

In this complex:

The metal ion is Ni^{2+}, nickel in the +2 oxidation state.

CN^- is cyanide, a monodentate ligand.

The overall charge of the complex is -2.

The IUPAC name for this complex is:

$$\text{tetra(cyanido)nickelate(II)}^{2-}$$

Quick Tip
When naming coordination complexes, follow these steps: 1. Name the ligands first, in alphabetical order, using prefixes like ”di-” or ”tri-” to indicate the number of identical ligands. 2. The metal comes after the ligands, with its oxidation state in Roman numerals in parentheses. 3. For anionic complexes, the metal name ends in ”-ate” (e.g., nickel becomes ”nickelate”). 4. Use common names for neutral ligands (e.g., ammonia for NH_3, water for H_2O).

---

26. (A) Explain the following reactions and write chemical equations involved:

(a) Wolff-Kishner reduction

(b) Etard reaction

(c) Cannizzaro reaction

Solution:

(a) Wolff-Kishner Reduction The Wolff-Kishner reduction is a method used to reduce a carbonyl group (C=O) to a methylene group (CH_2) by employing hydrazine (H_2NNH_2) in the presence of a strong base such as potassium hydroxide (KOH), with heating. This reaction effectively removes the oxygen atom from the carbonyl group, converting it into a hydrocarbon.

Reaction:

$$\text{R-CO-R'} + H_2NNH_2 \xrightarrow{\text{KOH, heat}} \text{R-CH}_2\text{R'}$$

This process reduces aldehydes or ketones to alkanes.

(b) Etard Reaction The Etard reaction involves the oxidation of toluene (methylbenzene) to benzaldehyde using chromium-based reagents such as chromium trioxide (CrO_3) or

pyridinium chlorochromate (PCC). In this reaction, an aldehyde group is added to the methyl group of toluene.

Reaction:

$$C_6H_5CH_3 + CrO_3 \rightarrow C_6H_5CHO$$

Here, toluene is oxidized to benzaldehyde.

(c) Cannizzaro Reaction The Cannizzaro reaction is a redox disproportionation reaction that occurs with aldehydes lacking an alpha hydrogen. In the presence of a strong base, one molecule of the aldehyde is reduced to an alcohol, while another is oxidized to a carboxylate anion.

Reaction:

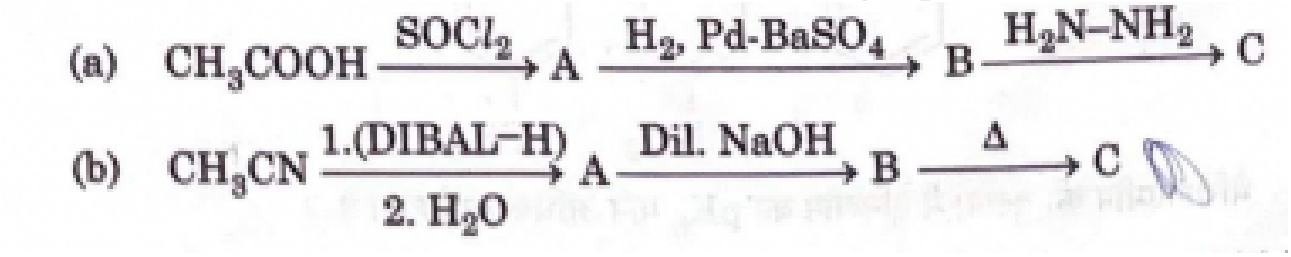
$$2\text{R-CHO} \xrightarrow{\text{strong base}} \text{R-CH}_2\text{OH} + \text{R-COO}^-$$

In this reaction, two molecules of aldehyde participate: one is reduced to alcohol, and the other is oxidized to a carboxylate.

Quick Tip
In the Wolff-Kishner reduction, remember that hydrazine and strong base under heat are used to reduce carbonyl compounds, whereas in the Cannizzaro reaction, aldehydes without alpha hydrogens undergo disproportionation.

OR

26. (B) Write the structures of A, B, and C in the following sequence of reactions:



Solution:

(a) Reaction Sequence:

1. $CH_3COOH \xrightarrow{SOCl_2} CH_3COCl$:

Acetic acid (CH_3COOH) reacts with thionyl chloride ($SOCl_2$) to form acetyl chloride (CH_3COCl), which is an acyl chloride.

2. $CH_3COCl \xrightarrow{H_2,\text{Pd-BaSO}_4} CH_3CH_2NH_2$:

The acetyl chloride undergoes a reduction reaction using hydrogen (H_2) in the presence of a palladium catalyst on barium sulfate (Pd-$BaSO_4$) to form ethylamine ($CH_3CH_2NH_2$).

3. $CH_3CH_2NH_2 \xrightarrow{H_2\text{N-NH}_2} C$:

The ethylamine ($CH_3CH_2NH_2$) reacts with hydrazine (H_2N-NH_2) to form a product C, which is likely a hydrazone or another nitrogen-containing compound.

(b) Reaction Sequence: 1. $CH_3CN \xrightarrow{1.\text{DIBAL-H},2.H}{}_2$ O A:

Methyl cyanide (CH_3CN) reacts with DIBAL-H (diisobutylaluminum hydride) to reduce the nitrile group (CN) to an aldehyde (CH_3CHO), which is compound A.

2. A $\xrightarrow{\text{NaOH, heat}}$ B:

The aldehyde A undergoes an aldol condensation in the presence of sodium hydroxide (NaOH) and heat, forming a product B, which is likely a -hydroxy aldehyde or ketone.

3. B $\xrightarrow{C}$ C:

The compound B undergoes further reactions, likely a dehydration or other transformation to form the final product C.

Quick Tip
In this reaction sequence, DIBAL-H is used to reduce nitriles to aldehydes, and aldol condensation with NaOH under heat leads to the formation of -hydroxy aldehydes or ketones, which can undergo further transformations to form the final product.

---

27. (a) Define the following:

(i) Enantiomers

(ii) Racemic mixture

Solution:

(i) Enantiomers:

Enantiomers are pairs of molecules that are mirror images of each other but cannot be superimposed. These molecules have the same physical properties but differ in how they

interact with plane-polarized light and with other chiral substances. For instance, the right- and left-handed forms of a chiral molecule are enantiomers.

(ii) Racemic mixture:

A racemic mixture consists of equal amounts of two enantiomers of a chiral compound. In such a mixture, the optical activities of the enantiomers cancel each other out, leading to no overall optical rotation.

Quick Tip
Enantiomers can be separated using chiral chromatography, while racemic mixtures can be resolved into their individual enantiomers through methods like recrystallization or enzymatic processes.

---

27. (b) Why is chlorobenzene resistant to nucleophilic substitution reactions?

Solution: Chlorobenzene is resistant to nucleophilic substitution due to the electron-withdrawing effect of the chlorine atom, which decreases the electron density on the benzene ring. This makes the carbon attached to the chlorine less electrophilic, which reduces its ability to undergo nucleophilic attack. Additionally, the resonance stabilization of the chlorine atom with the aromatic ring further makes the carbon-chlorine bond stronger, thus making nucleophilic substitution less favorable.

Quick Tip
The electron-withdrawing effect of the chlorine atom and the resonance stabilization in chlorobenzene make it resistant to nucleophilic substitution reactions, unlike alkyl halides where such substitution is easier.

---

28. (a) Write the product obtained when D-glucose reacts with $H_2N - OH$.

Solution: When D-glucose reacts with hydroxylamine ($H_2N - OH$), it forms an oxime. The aldehyde group of D-glucose reacts with hydroxylamine, resulting in the formation of a stable oxime with the general structure $R - C = N - OH$, where R represents the rest of the

glucose molecule. In this reaction, the glucose aldehyde undergoes a nucleophilic addition to yield the corresponding oxime.

Quick Tip
Hydroxylamine reacts with aldehydes and ketones to produce oximes, which serve as valuable intermediates in organic synthesis.

---

28. (b) Amino acids show amphoteric behaviour, why?

Solution: Amino acids exhibit amphoteric behavior because they contain both acidic and basic functional groups. The amino group ($-NH_2$) can function as a base by accepting protons, while the carboxyl group ($-COOH$) can donate protons, acting as an acid. This dual functionality allows amino acids to behave as both acids and bases, depending on the pH of the solution, illustrating their amphoteric nature.

Quick Tip
Amino acids can exist in various ionic forms (zwitterions) based on the pH, where the amino group is protonated (NH_3^+) and the carboxyl group is deprotonated (COO^-).

---

28. (c) Why can't vitamin C be stored in our body?

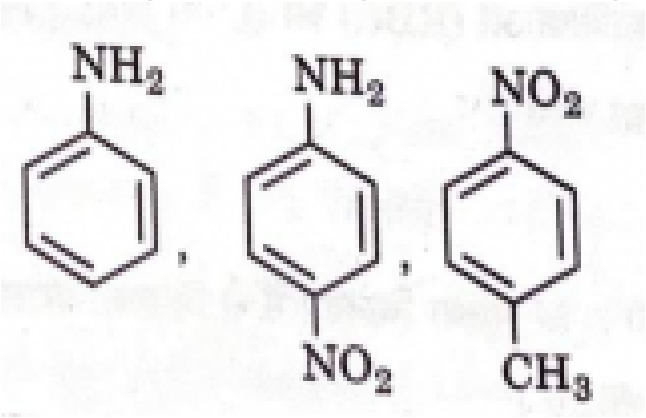
Solution: Vitamin C (ascorbic acid) cannot be stored in the body because it is water-soluble, and the body lacks the ability to store water-soluble vitamins. As a result, any excess vitamin C is excreted in the urine. To maintain sufficient levels of vitamin C, it is crucial to include it regularly in the diet since the body cannot store it for extended periods.

Quick Tip
Since vitamin C is not stored in the body, it needs to be consumed regularly. Good sources of vitamin C include citrus fruits, tomatoes, and green leafy vegetables.

SECTION -D

29. Amines have a lone pair of electrons on nitrogen atom due to which they behave as Lewis base. Greater the value of K_b or smaller the value of pK_b, stronger is the base. Amines are more basic than alcohols, ethers, esters, etc. The basic character of aliphatic amines should increase with the increase of alkyl substitution. But it does not occur in a regular manner as a secondary aliphatic amine is unexpectedly more basic than a tertiary amine in aqueous solutions. Aromatic amines are weaker bases than ammonia and aliphatic amines. Electron releasing groups such as $-CH_3$, $-NH_2$, etc., increase the basicity while electron-withdrawing substituents such as $-NO_2$, –CN, halogens, etc., decrease the basicity of amines. The effect of these substituents is more at the p than at m position.

(a) Arrange the following in the increasing order of their basic character. Give reason:



Solution:

Step 1: Understanding the Factors Influencing Basicity

The basicity of amines is mainly determined by the electron density on the nitrogen atom. The more electron-donating the substituents, the more basic the amine will be, as they enhance the availability of the nitrogen's lone pair for protonation. On the other hand, electron-withdrawing groups decrease the electron density on nitrogen, reducing its basicity. Electron-donating groups (like $-NH_2$ and $-CH_3$) increase the basicity by raising the electron density on nitrogen.

Electron-withdrawing groups (such as $-NO_2$ and $-CN$) decrease the basicity as they pull electron density away from nitrogen, making the lone pair less available to accept a proton.

Step 2: Analyzing the Substituents

Now, let's analyze the substituents attached to the nitrogen atoms in the given compounds:
$-NH_2$ is an amine group, an electron-donating group. It will increase the electron density on nitrogen, making the amine more basic.
$-NO_2$ is a strong electron-withdrawing group. It pulls electron density away from nitrogen, reducing the availability of the lone pair and lowering the basicity.
$-CH_3$ is also an electron-donating group, but weaker than $-NH_2$. Therefore, it increases basicity, but not as strongly as $-NH_2$.

Step 3: Arranging in Order of Basicity

Now, let's rank the compounds based on the strength of their electron-donating or electron-withdrawing effects:
$-NO_2$ (electron-withdrawing) will have the lowest basicity.
$-NO_2$ (when positioned para) will be less basic than $-NH_2$ due to the electron-withdrawing nature of $-NO_2$.
$-NH_2$ will be the most basic because it is a strong electron-donating group.
$-CH_3$ is a mild electron-donating group, so it will be more basic than $-NO_2$, but less basic than $-NH_2$.
Therefore, the increasing order of basicity is:

$$NO_2 < NO_2 < CH_3 < NH_2$$

Quick Tip
The basicity of amines is determined by the electron-donating or electron-withdrawing effect of the substituents attached to the nitrogen. Electron-donating groups increase basicity, while electron-withdrawing groups decrease it.

---

29. (b) Why pK of aniline is more than that of methylamine?

Solution:

Step 1: Understanding Basicity

The basicity of amines refers to the ability of the nitrogen atom to donate its lone pair of electrons to a proton. The higher the availability of the nitrogen's lone pair for protonation, the greater the basicity.

In aniline (CHNH), the nitrogen's lone pair can participate in resonance with the benzene ring, reducing its availability for protonation. This lowers the electron density on the nitrogen, making aniline a weaker base compared to methylamine (CHNH), where the methyl group is an electron-donating group. The methyl group increases the electron density on nitrogen, making the lone pair more available for protonation and enhancing the basicity.

Step 2: Resonance Effect in Aniline In aniline, the nitrogen's lone pair can be delocalized into the aromatic ring through resonance, forming a structure where the lone pair is less available for protonation. This resonance effect decreases the basicity of aniline when compared to methylamine.

Step 3: Methylamine and the Inductive Effect Methylamine, in contrast, has a methyl group (–CH) attached to nitrogen. The methyl group donates electrons via the inductive effect, increasing the electron density on nitrogen and making its lone pair more available for protonation, which increases the basicity.
As a result, methylamine has a greater basicity than aniline, leading to a higher pK for methylamine compared to aniline.

Quick Tip
The basicity of aromatic amines like aniline is reduced due to resonance with the aromatic ring, while aliphatic amines like methylamine are more basic due to the electron-donating inductive effect of the alkyl group.

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29. (c) (i) Arrange the following in the increasing order of their basic character in an aqueous solution:

$(CH_3)_3N$, $(CH_3)_2NH$, NH_3, CH_3NH_2

Solution:

Step 1: Understanding the Effect of Alkyl Groups on Basicity The basicity of amines in aqueous solutions increases with the number of alkyl groups attached to the nitrogen atom. Alkyl groups are electron-donating groups, and they increase the electron density on

nitrogen, making the lone pair more available to accept a proton.
Trimethylamine $(CH_3)_3N$ has three methyl groups attached to nitrogen, making it highly electron-donating and thus the most basic.
Dimethylamine $(CH_3)_2$NH has two methyl groups, so it is also basic, but not as basic as trimethylamine.
Methylamine (CH_3NH_2) has one methyl group, which donates less electron density than two or three groups.
Ammonia (NH_3) has no alkyl groups, so it is the least basic.

Step 2: Arranging in Order of Basicity The increasing order of basicity is:

$$(NH_3) < (CH_3NH_2) < (CH_3)_2NH < (CH_3)_3N$$

Quick Tip
The basicity of amines increases as the number of electron-donating alkyl groups attached to nitrogen increases. Alkyl groups push electron density towards the nitrogen, enhancing the availability of its lone pair for protonation.

OR

29. (c) (ii) Why ammonolysis of alkyl halides is not a good method to prepare pure amines?
Solution:
Step 1: The Ammonolysis Process Ammonolysis of alkyl halides involves the reaction of an alkyl halide with ammonia (NH_3), where the nucleophilic nitrogen from ammonia attacks the electrophilic carbon in the alkyl halide. This displaces the halide ion and forms a primary amine.
However, this reaction has a significant limitation: the product amine can further react with excess alkyl halide, resulting in the formation of secondary and tertiary amines.

Step 2: Multiple Reactions The alkyl groups attached to the nitrogen of the amines formed during ammonolysis can cause the reaction to proceed further, leading to secondary and

tertiary amines. This results in a mixture of amines, rather than a pure primary amine. For example, if methylamine (CH_3NH_2) is formed in the first step, it can react with another molecule of alkyl halide to form dimethylamine (CH_3NHCH_3), and further to trimethylamine ($CH_3N(CH_3)_2$).

Step 3: Alternative Methods To obtain pure primary amines, alternative methods such as reductive amination or Gabriel synthesis are preferred. These methods avoid the formation of secondary and tertiary amines.

Quick Tip
Ammonolysis of alkyl halides often leads to a mixture of primary, secondary, and tertiary amines. To avoid this, alternative synthetic methods, like Gabriel synthesis, can be used to obtain pure primary amines.

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30. The spontaneous flow of the solvent through a semipermeable membrane from a pure solvent to a solution or from a dilute solution to a concentrated solution is called osmosis. The phenomenon of osmosis can be demonstrated by taking two eggs of the same size. In an egg, the membrane below the shell and around the egg material is semipermeable. The outer hard shell can be removed by putting the egg in dilute hydrochloric acid. After removing the hard shell, one egg is placed in distilled water and the other in a saturated salt solution. After some time, the egg placed in distilled water swells up while the egg placed in salt solution shrinks. The external pressure applied to stop the osmosis is termed as osmotic pressure (a colligative property). Reverse osmosis takes place when the applied external pressure becomes larger than the osmotic pressure.

(a) Define reverse osmosis. Name one SPM which can be used in the process of reverse osmosis.

Solution: Reverse osmosis is a process where solvent moves from a solution with a higher concentration to one with a lower concentration through a semipermeable membrane. However, this occurs only when external pressure is applied that exceeds the osmotic pressure, reversing the natural osmotic flow.

A common example of a semipermeable membrane (SPM) used in reverse osmosis is cellulose acetate.

Quick Tip
Reverse osmosis is the process of driving solvent through a semipermeable membrane from a more concentrated solution to a less concentrated one by applying pressure greater than the osmotic pressure. It is widely used for water purification.

---

30. (b) (i) What do you expect to happen when red blood corpuscles (RBC's) are placed in 0.5% NaCl solution?

Solution: When red blood cells (RBCs) are placed in a 0.5% NaCl solution, which is hypotonic compared to the intracellular fluid, water moves into the RBCs by osmosis. This results in the cells swelling as water enters. If too much water accumulates, the RBCs may rupture, a process called hemolysis.

Quick Tip
Hypotonic solutions cause water to move into RBCs by osmosis, leading to swelling and potentially causing the cells to burst (hemolysis).

OR

30. (b) (ii) Which one of the following will have higher osmotic pressure in 1 M KCl or 1 M urea solution? Justify your answer.

Solution: Osmotic pressure is directly proportional to the number of solute particles in solution. Since KCl dissociates into two ions (K^+ and Cl^-) in solution, a 1 M KCl solution will have a higher osmotic pressure than a 1 M urea solution, which does not dissociate into ions. Therefore, the 1 M KCl solution will have a higher osmotic pressure.

Quick Tip

Osmotic pressure depends on the number of particles in solution. Ionic compounds like KCl dissociate into more particles, increasing osmotic pressure compared to non-ionic compounds like urea.

---

30. (c) Why osmotic pressure is a colligative property?

Solution: Osmotic pressure is a colligative property because it depends only on the number of solute particles in a solution, not on their nature or identity. The greater the number of solute particles, the higher the osmotic pressure, regardless of whether the solute is ionic or non-ionic.

Quick Tip

Osmotic pressure is a colligative property because it depends on the concentration of solute particles in a solution, not their chemical nature.

---

31. (A) An organic compound A, molecular formula C_2H_6O, oxidises with Cr_2O_7 to form a compound B. Compound B on warming with iodine and aqueous solution of NaOH gives a yellow precipitate of compound C. When compound A is heated with conc. H_2SO_4 at 413 K, it gives a compound D, which on reaction with excess HI gives compound E. Identify compounds A, B, C, D, and E and write chemical equations involved.

Solution:

Compound A has the molecular formula C_2H_6O, indicating that it is ethanol.

When ethanol is oxidized by Cr_2O_7, it forms acetic acid (CH_3COOH), which is compound B.

When acetic acid reacts with iodine and NaOH, it produces a yellow precipitate of iodoform (CHI_3), which is compound C.

When ethanol is heated with concentrated H_2SO_4 at 413 K, it undergoes dehydration to form ethene (C_2H_4), which is compound D.

When ethene reacts with excess HI, it forms iodoethane (C_2H_5I), which is compound E.

The chemical equations involved are as follows:

1. $C_2H_5OH + Cr_2O_7^{2-} \rightarrow CH_3COOH$

2. $CH_3COOH + I_2 + NaOH \rightarrow CHI_3$ (yellow precipitate)

3. $C_2H_5OH \xrightarrow{H_2SO_4, 413K} C_2H_4 + H_2O$

4. $C_2H_4 + I_2 \rightarrow C_2H_5I$

Quick Tip
The iodoform test (formation of a yellow precipitate) is used to detect compounds containing the structure CH_3CO or CH_3CH, such as aldehydes and alcohols.

OR

31. (B) (a) Write chemical equations of the following reactions: (i) Phenol is treated with conc. HNO_3.

(ii) Propene is treated with B_2H_6 followed by oxidation by H_2O_2/OH^-.

(iii) Sodium t-butoxide is treated with CH_3Cl.

Solution:

1. Phenol treated with conc. HNO_3: Phenol reacts with concentrated nitric acid (HNO_3) to form a mixture of nitrophenols. The reaction is as follows:

$$C_6H_5OH + HNO_3 \rightarrow 2,4,6 - \text{Nitrophenol} + H_2O$$

2. Propene treated with B_2H_6 followed by oxidation by H_2O_2/OH^-: The hydroboration-oxidation reaction of propene results in the formation of an alcohol:

$$C_3H_6 + B_2H_6 \rightarrow C_3H_7B \quad \text{(Hydroboration)}$$

Followed by oxidation:

$$C_3H_7B + H_2O_2/OH^- \rightarrow C_3H_7OH \quad \text{(Propan-2-ol)}$$

3. Sodium t-butoxide treated with CH_3Cl: Sodium t-butoxide undergoes nucleophilic substitution with methyl chloride to form t-butyl methyl ether:

$$(CH_3)_3CO^- + CH_3Cl \rightarrow (CH_3)_3COCH_3$$

Quick Tip

The hydroboration-oxidation of alkenes adds water in a syn fashion, which is different from the anti-addition in acid-catalyzed hydration.

---

31. (B) (b) Give a simple chemical test to distinguish between butan-1-ol and butan-2-ol.

Solution: A straightforward chemical test to differentiate between butan-1-ol and butan-2-ol is the oxidation test using potassium dichromate ($K_2Cr_2O_7$) in an acidic medium. Butan-1-ol will be oxidized to butanoic acid, while butan-2-ol will be oxidized to acetone.

Butan-1-ol: Upon oxidation, it forms a carboxylic acid, butanoic acid.

Butan-2-ol: Upon oxidation, it forms a ketone, acetone.

Another test involves the reaction with iodine and NaOH:

Butan-1-ol forms a yellow precipitate of iodoform when treated with iodine and NaOH.

Butan-2-ol also forms a yellow precipitate of iodoform, but the intensity of the reaction can be used for differentiation.

Quick Tip

The oxidation test and iodoform test can help distinguish between primary and secondary alcohols. Primary alcohols are oxidized to carboxylic acids, while secondary alcohols form ketones.

---

31. (c) Arrange the following in increasing order of acid strength: phenol, ethanol, water.

Solution: To arrange these compounds in increasing order of acid strength, we consider the ability of these compounds to donate a proton. The stronger the ability to donate a proton (H^+), the stronger the acid.

1. Ethanol (CH_3CH_2OH): Ethanol has a hydroxyl group (-OH) but it is a very weak acid compared to water or phenol. 2. Water (H_2O): Water is neutral but can act as a weak acid, donating a proton to form OH^-. 3. Phenol (C_6H_5OH): Phenol is a stronger acid than both ethanol and water due to the resonance stabilization of the phenoxide ion ($C_6H_5O^-$) after

proton donation.

Thus, the increasing order of acid strength is:

$$\text{Ethanol} < \text{Water} < \text{Phenol}$$

Quick Tip
The acidity of alcohols and phenols increases with the ability to stabilize the conjugate base. Phenols are more acidic due to the resonance stabilization of the phenoxide ion.

---

32. (A) (a) Give IUPAC name of $CH_3 = CH - CH = CH - CHO$.

Solution: The IUPAC name of the compound $CH_3 = CH - CH = CH - CHO$ is pent-2,4-enal.

The compound consists of a 5-carbon chain with two double bonds at positions 2 and 4.

The aldehyde group ($-CHO$) is located at the end of the chain, and the suffix "-al" is used to indicate the aldehyde functional group.

Thus, the IUPAC name is pent-2,4-enal.

Quick Tip
When naming compounds with multiple functional groups, the highest-priority functional group is given the lowest possible number, and double bonds are numbered to ensure the lowest positions.

---

32. (b) Give a simple chemical test to distinguish between propanal and propanone.

Solution: A simple chemical test to differentiate between propanal (an aldehyde) and propanone (a ketone) is the Tollens' test.

Propanal (Aldehyde): When treated with Tollens' reagent (ammoniacal silver nitrate), aldehydes reduce silver ions to metallic silver, creating a silver mirror on the inner surface of the test tube.

Propanone (Ketone): Ketones do not react with Tollens' reagent and, therefore, do not form a silver mirror.

Thus, the Tollens' test effectively distinguishes between an aldehyde and a ketone.

Quick Tip
The Tollens' test is a traditional method to identify aldehydes. Aldehydes reduce silver ions to form a silver mirror, whereas ketones do not react.

---

32. (c) How will you convert the following:

(i) Toluene to benzoic acid.

(ii) Ethanol to propan-2-ol.

(iii) Propanal to 2-hydroxy propanoic acid.

Solution:

1. Toluene to benzoic acid: Toluene can be oxidized to benzoic acid by treating it with potassium permanganate ($KMnO_4$).

$$C_6H_5CH_3 + KMnO_4 \rightarrow C_6H_5COOH$$

This is a typical oxidation reaction where the methyl group (-CH_3) is oxidized to a carboxyl group (-COOH).

2. Ethanol to propan-2-ol: Ethanol can be converted to propan-2-ol by using a suitable catalyst for a reduction reaction. For example, it can be oxidized to acetaldehyde (CH_3CHO), which is then reduced to propan-2-ol using a reducing agent like lithium aluminum hydride ($LiAlH_4$).

$$C_2H_5OH \xrightarrow{[O]} C_2H_4O \xrightarrow{LiAlH_4} C_3H_7OH$$

Alternatively, it can be directly hydrated from propene.

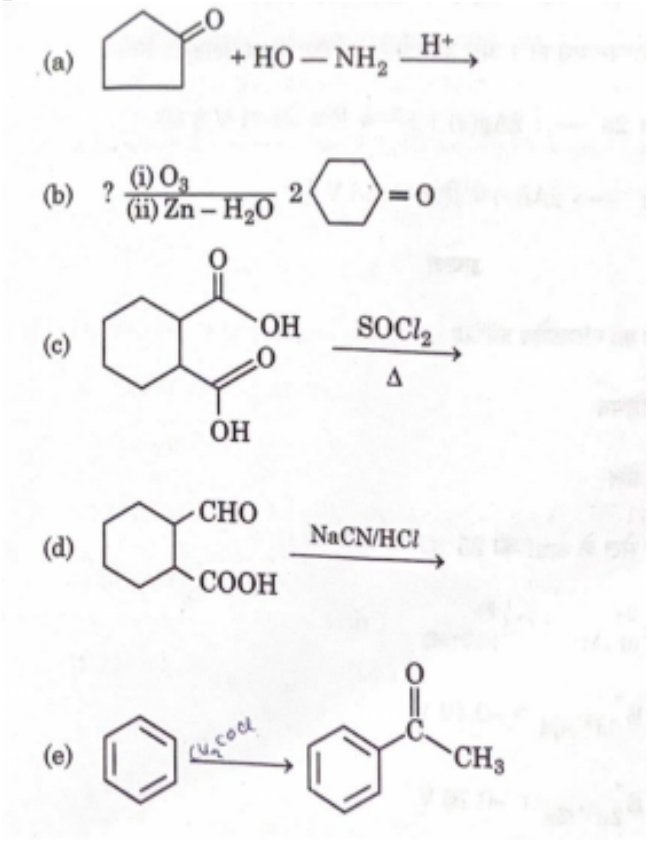
3. Propanal to 2-hydroxy propanoic acid: Propanal can be converted to 2-hydroxy propanoic acid by the hydroxylation reaction, specifically by adding a hydroxyl group to the alpha-carbon of the aldehyde. A suitable reagent for this transformation is hydroxylamine or a mild oxidizing agent.

$$C_3H_7CHO + OH^- \rightarrow C_3H_6(OH)COOH$$

Quick Tip
The oxidation of toluene with potassium permanganate is a strong method to obtain benzoic acid. Hydration of propene and reduction of aldehydes are common transformations in organic synthesis.

OR

32. (B) Complete each synthesis by giving missing starting material, reagent, or products:



Solution:

(a)

$$O + HO - NH2 \xrightarrow{H+} NH2OH$$

The reaction involves the formation of hydroxylamine ($NH2OH$) from an aldehyde (O) and hydroxylamine ($HO - NH2$) in the presence of an acid catalyst ($H+$).

(b)

$$CH2 = CH2 \xrightarrow{\text{(i) } O_3 \text{ (ii) } Zn-H_2O} 2HCHO \xrightarrow{\Delta} \text{No further change}$$

The reaction involves ozonolysis of ethene ($CH2 = CH2$) followed by reductive workup to form formaldehyde ($HCHO$). Heating (Δ) does not change the product further.

(c)

$$OH \xrightarrow{SOCl2} Cl$$

The reaction involves the conversion of an alcohol (OH) to an alkyl chloride (Cl) using thionyl chloride ($SOCl2$) under heating (Δ).

(d)

$$CHO \xrightarrow{NaCN/HCl} COOH$$

The reaction involves the conversion of an aldehyde (CHO) to a carboxylic acid ($COOH$) using sodium cyanide ($NaCN$) and hydrochloric acid (HCl).

(e)

$$Cl2C6H5 \xrightarrow{CH3} Cl2C6H4CH3$$

The reaction involves the methylation of chlorobenzene ($Cl2C6H5$) to form a methylated chlorobenzene derivative ($Cl2C6H4CH3$).

Quick Tip

Quick Tips for Organic Synthesis:

- **(a)** Aldehydes react with hydroxylamine ($HO - NH2$) in the presence of an acid to form oximes, which are useful intermediates in organic synthesis.
- **(b)** Ozonolysis cleaves double bonds in alkenes, producing carbonyl compounds (aldehydes or ketones) depending on the structure of the starting alkene.
- **(c)** Thionyl chloride ($SOCl2$) is a common reagent for converting alcohols to alkyl chlorides, with gaseous byproducts ($SO2$ and HCl) that are easy to remove.
- **(d)** Aldehydes can be converted to carboxylic acids using sodium cyanide ($NaCN$) and hydrochloric acid (HCl) via cyanohydrin formation and hydrolysis.
- **(e)** Electrophilic aromatic substitution reactions, such as methylation, introduce substituents like $CH3$ onto the benzene ring, commonly seen in aromatic compounds.

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33. (A) (a) Calculate the standard Gibbs energy (ΔG°) of the following reaction at 25°C:

$$\text{Au}(s) + \text{Ca}^{2+}(1M) \rightarrow \text{Au}^{3+}(1M) + \text{Ca}(s)$$

$$E^\circ_{\text{Au}^{3+}/\text{Au}} = +1.5\,\text{V}, \quad E^\circ_{\text{Ca}^{2+}/\text{Ca}} = -2.87\,\text{V}$$

Predict whether the reaction will be spontaneous or not at 25°C. [1 F = 96500 C mol^{-1}]

Solution: The standard Gibbs free energy change (ΔG°) is related to the standard electrode potential change (ΔE°) using the following equation:

$$\Delta G^\circ = -nF\Delta E^\circ$$

Where:

n is the number of moles of electrons transferred in the reaction (which is 3 for this reaction).
F is the Faraday constant ($96500\,\text{C mol}^{-1}$).
ΔE° is the cell potential, calculated as:

$$\Delta E^\circ = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = 1.5 - (-2.87) = 4.37\,\text{V}.$$

Now, calculating ΔG°:

$$\Delta G^\circ = -3 \times 96500 \times 4.37 = -1.26 \times 10^6\,\text{J/mol}.$$

Since ΔG° is negative, the reaction is spontaneous.

Quick Tip
A negative value for ΔG° indicates that the reaction is spontaneous. The magnitude of ΔG° is directly related to the cell potential, which can be determined using the Nernst equation.

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33. (b) Tarnished silver contains Ag_2S. Can this tarnish be removed by placing tarnished silverware in an aluminium pan containing an inert electrolytic solution such as NaCl? The standard electrode potential for the half reaction:

$$\mathbf{Ag_2S}(s) + 2e^- \rightarrow 2\mathbf{Ag}(s) + S^{2-}(aq)\,(\mathbf{E}^\circ = -0.71\,\mathbf{V})$$

$$\mathbf{Al}^{3+}(aq) + 3e^- \rightarrow \mathbf{Al}(s)\,(\mathbf{E}^\circ = -1.66\,\mathbf{V})$$

Solution: The reaction involves the reduction of Ag_2S to silver, and the oxidation of aluminium to aluminium ion. The cell potential for this reaction is the difference between the reduction potential of silver and aluminium:

$$\Delta E^\circ = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = (-0.71) - (-1.66) = 0.95\,\text{V}.$$

Since the cell potential is positive, the reaction is spontaneous, meaning that tarnish can be removed by using an aluminium pan containing NaCl.

Quick Tip

In electrochemical reactions, the substance with the more positive reduction potential (cathode) will be reduced, and the one with the more negative reduction potential (anode) will be oxidized.

OR

33. (B) (a) (i) Define the following:

(i) Cell potential

Solution: Cell potential is the difference in the electric potential between two electrodes in an electrochemical cell. It is a measure of the ability of a redox reaction to occur spontaneously. The cell potential is typically measured in volts (V) and is denoted by E_{cell}. The higher the cell potential, the greater the driving force for the reaction.

Quick Tip

The cell potential is calculated as the difference between the reduction potentials of the cathode and anode, and it indicates the direction of electron flow in an electrochemical cell.

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33. (a) (ii) Fuel cell

Solution: A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (such as hydrogen or methanol) into electrical energy through a redox reaction. The reactants are continuously supplied to the cell, and the products are continuously removed. The most common example is the hydrogen fuel cell, where hydrogen reacts with oxygen to produce water and electricity.

Quick Tip

Fuel cells are environmentally friendly because their only byproduct is usually water, making them an important alternative to traditional power sources.

33. (b) Calculate emf of the following cell at 25°C:

$$\text{Zn}(s)\,|\,\text{Zn}^{2+}(0.1M)\,||\,\text{Cd}^{2+}(0.01M)\,|\,\text{Cd}(s)$$

Given:

$$E^\circ_{\text{Zn}^{2+}/\text{Zn}} = -0.40\,\text{V}, \quad E^\circ_{\text{Cd}^{2+}/\text{Cd}} = -0.76\,\text{V}.$$

Solution: The emf of the cell can be determined using the Nernst equation:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0592}{n} \log \left(\frac{[\text{products}]}{[\text{reactants}]} \right)$$

Where:

$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$.

$n = 2$ (the number of electrons transferred).

The standard cell potential is:

$$E^\circ_{\text{cell}} = (-0.76) - (-0.40) = -0.36\,\text{V}.$$

Substituting values into the Nernst equation:

$$E_{\text{cell}} = -0.36 - \frac{0.0592}{2} \log \left(\frac{0.01}{0.1} \right)$$

$$E_{\text{cell}} = -0.36 - \frac{0.0592}{2} \log(0.1)$$

$$E_{\text{cell}} = -0.36 - \frac{0.0592}{2} \times (-1) = -0.36 + 0.0296 = -0.33\,\text{V}.$$

Thus, the emf of the cell at 25°C is $-0.33\,\text{V}$.

Quick Tip
The Nernst equation is used to calculate the emf of an electrochemical cell under non-standard conditions by considering the ion concentrations.